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Technical Memo No. 221

REPORT ON SPECIAL MEETING TO DISCUSS NONDESTRUCTIVE TESTS FOR FILAMENT WOUND FIBERGLASS MOTOR CASES

AT

AEROJET-GENERAL CORPORATION
SACRAMENTO

ON
24-25 January 1963

By

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Report on Special Meeting To Discuss Nondestructive Tests for Filament Wound Fiberglass Motor Cases at AGC - Sacramento on 24-25 January 1963

A special meeting of the Polaris/Minuteman/Pershing NDT Committee was held at AGC-Sacramento on 24-25 January 1963 to discuss techniques for inspection of fiberglass chambers. Unfortunately, only Polaris people took part, but there was an observer from S.T.L. (Minuteman).

Harold Bernstein, in his opening remarks for SPO, pointed out that our situation is much different now with fiberglass as compared to steel. With steel we felt that we knew our material, could specify maximum flaw size, and had reliable NDT and other techniques for quality control. We could hydrotest a steel case several times at design pressure and use NDT methods for detection of damage during hydrotest. On the other hand a fiberglass case has one hydrotest and no established, reliable NDT.

While we have had firing failures directly attributed to case damage during hydrotest, the complete elimination of hydrotest is not desired, for as Mr. Bernstein so aptly said, "Virginity is no proof of virtue".

We need supplementary tests. We need to increase coverage (100% coverage if possible) and to reduce cost. (We can get 100% coverage by x-ray, but at great cost.)

We then heard from J. A. Hendron of AGC about the status of the AGC A-3 Polaris Master Plan for NDT. Accept-reject criteria are fairly firm with the exception of x-ray on the glass-wrap. AGC appears to use or contemplate using about every NDT technique known at this time, including candling for voids in the insulator. Other techniques mentioned were ultrasonics, x-ray, corona discharge, microwave, beta-back scatter, spark test, stati-flux, and moisture detector. Ultrasonic and x-ray techniques are conventional, but more about ultrasonics below. Spark test is used to detect through-holes. Corona discharge and microwaves can detect voids in insultation and glass-wrap. Beta-ray back scatter can be used to measure resin content on the finished case, but only to a limited depth. Candling is also used on the completed chamber. Two suggestions were made from the table of this time to use a Borescope or a telescope system called "Optro" (Sp?) to keep personnal out of the chamber as much as possible. Stati-flux is used to detect cracks and crasing on the completed chamber. Percentage moisture level is monitored with an electronic moisture detector. This latter test is for the purpose of gathering information on the effects of moisture on chamber performance as requested by NRL and SPO.

In connection with ultrasonics, the AUWI Modification will be used to automatically inspect and record the cylindrical section for unbond and delaminations.

R. Steele and A. Green of AGC spoke on sonic analysis of hydrotest. They found that there is a radial displacement of the fiberglass at the edge of the nozzle port and this seems to occur at a pressure of 700-945 psi. This is believed to be indicative of a stress relief which leads to knuckle failure or a delamination which leads to the so called flower bursts.

Accelerometers are better for listening than microphones because 1) they have wider frequency range; 2) have less extraneous noise; 3) they are more easily calibrated; 4) being smaller they give better resolution.

As part of the program they measured sound velocity in Fiberglass. This was done by tapping with a ball at a known distance from the accelerometer and recording delay time on a tape recorder running at 60 ips. By playing back at 0.6 ips the tap and received signal could be separated and the time measured. They record 190 K in/sec in the plane of the fiberglass in the direction of wrap. This is of course at sonic frequencies.

KRL has measured the velocity at 1.0 Mc to be 192 K in/sec in the axial direction (parallel to axis of motor case) and 187 K in/sec in the circumferential direction. The outer circumferential winding comprises almost half the thickness. A velocity of 205 K in/sec was measured in this layer. Through-the-thickness velocity was 121 K in/sec. The sample was cut from an AGC A-3 first stage.

Mr. D. T. O'Connor described experiments being run at Magnaflux Corp. on the use of Corona discharge, Beta-ray back scatter, and microwave techniques for inspecting motor cases. Beta back scatter has limited penetration, but could be used for resin content to the extent it penetrates. As such it does not appear feasible for motor case inspection. Corona discharge is ionization in a gaseous void in a solid caused by a strong electric field. This ionization may be detected by the radiation it produces or by the pulse that occurs in the high voltage transformer. It can detect voids 1/16" in diameter in the fiberglass-resin matrix. A distinct separation of the walls of the void is not necessary. Microwaves are used by setting up standing waves and measuring the effect on them of different properties of the materials in the field. A void has a different propagation factor, hence different wavelength from the parent material. Changes in standing wave pattern are indicated on suitable detecting instruments. It was stated that, as compared to ultrasonics which can detect only unbonds and delaminations, microwaves can detect foreign inclusions and tiny bubbles. The microwave system requires a metallic reflector on the other side of the motor case wall. Scan time for cylindrical section for both microwave and corona discharge were estimated at 4 hours.

Mr. D. C. Erdman described his developments in the field of frequency-modulated pulsed ultrasonics. He pointed out that the inhomogeneous nature of the fiberglass causes severe scattering at conventional ultrasonic frequencies. Lower frequencies are transmitted better but pulses get so long that the transmitted pulse is still going out when echoes are returning. To get around this Erdman uses a pulse that is linearly modulated in frequency (100 kc - 300 kc). Thus the echo that comes back will not be at the same frequency as the portion of the transmitted pulse that is still going out. Presently resolution below surface is only 1/4 to 3/8 of an inch, but a differentiator as in the "Immerscope" should improve this. With this technique it may be possible to inspect the whole case for bonds and delaminations. The low frequency works against finding small defects such as bubbles.

Mr. P. E. Underhill of AGN described a TV readout x-ray scan system (PICS) which uses a bundle of fine plastic filaments with scintillators dispersed in the plastic. This gives a directionality which enhances the scintillator output which in turn is converted to TV readout with an image orthicon. This system looks promising as a scanning system. NOL has indicated that they will help out in the development of this system.

John Hendron returned to say a few words about tap tests. The inspector has to be able to distinguish pitches 5 cps apart. Correlation was about 80% with Betatron where comparison was made. Tap tests don't detect a deep delamination under a shallow one. When asked about evaluation Mr. Hendron said that the motor case that showed most delamination went to highest pressure in the burst test.

Mr. A. D. Lucian of AGC described the start of a program of analyzing NDT data. The first step is to classify defects. Voids are recorded as to area, cracks as to length, delaminations as to area, etc. and these are given weights of 1 to 5 depending on their severity. Correlation with performance is not yet available. Asked what areas are weakest with regard to gathering information, Mr. Lucian replied that the knuckle area is worst.

Mr. R. J. Downey briefly described NDT at ABL. X-ray is used to detect resin pockets, delaminations (usually range 1/4" to 2" long and to 1/32" wide), and voids (which are rare). He said no ABL motor failure has been correlated with known fiberglass defects. Moisture readings are being taken as at AGC. No correlation has been found with performance as yet. Some experiments have been tried with neutron radiography. These are interesting but the question arose as to where we get neutrons. ABL also uses Static flux, High contrast radiography, Sonoray with low frequency adaptor and have corona discharge available.

Mr. F. E. Alzofon of LMSC presented his infrared experiments. Indications are obtained from resin inclusions, case-linear unbond, and wall thickness. Ability to scan the ends of the motor case depends on whether the whole inner surface can be heated.

Mr. J. A. Cusick of NAD-Concord described experiments using mechanical impedance measurements to detect motor case defects. Mechanical impedance, the ratio of force to velocity, can be measured with suitable equipment. It may be possible to use instead the ratio and/or phase angle of force to acceleration. Oscillograms were presented showing that force and acceleration behave in opposite sense over a separation and over sound material. It was pointed out that the system could detect delaminations under delaminations. There is a possibility that the force generator could be applied axially at the skirt end and velocity, acceleration, or displacement readings taken radially along the cylinder section or at the other end of the case. It would also be possible to apply a force radially by means of an eccentric located in a central boss at either dome. If mechanical impedance works out it should be a quick and relatively inexpensive method for motor case scanning.

Mr. S. D. Hart of NRL described a novel approach to ultrasonic inspection. The brain child of W. J. Fry of the University of Illinois, the system uses high power focused ultra sound to cause local heating in a small space. The heating will cause changes in velocity which will produce an impedance difference where before there was none. If the material in the small spot being irradiated has an absorption coefficient different from its surroundings it will be heated differently and will display a different acoustic impedance, hence there will be a reflection coefficient at the boundary. Thus areas which before had the same acoustic impedance now are different and can be detected. Detection is accomplished by sending out conventional ultrasound pulses near the end or after the heating pulse. Fry has some of the equipment built and when funds are allotted will start constructing the necessary high power transducer. Powers in the order of many kilowatts per square centimeter may be needed.

J. A. Kies of NRL presented, at the request of SPO a list of defects which have been known to cause or are believed to have caused failure in fiberglass motor cases. This was an "off the top of the head" list, but any errors are probably errors of omission.

1. Debond between aft adapter plate and EP87 insulation.
2. Poor doily geometry.
3. No overlap in doilies in front end.
4. Cracks in snap-ring channel in aft adapter plate.
5. Debond between fiberglass and aft adapter plate.
6. Accidental machine tool cuts.
7. Knots in roving.
8. Rumpled (folded) doilies.
9. Too little glass in spiral wound doilies.
10. Relaxed rovings.
11. Poor interlaminar shear strength or poor adhesion (doilies improperly B-staged or resins incompatible).
12. Prepreg roving cure too far advanced at time of winding.
13. Cracks in EP87 insulation.

Of these, only four are considered serious in terms of need for detection in the fiberglass. These are cuts, delaminations, resin rich areas and, not on the list, bruises or impact damage. Such things as items 7, 9, 11, 12 are considered to be process control matters.

Dr. Bujes of NAD-Concord made some comments on the limitations and ultimate sensitivity of radiography. He showed slides of x-rays in which he pointed out individual rovings in a fiberglass case.

He presented some data on low voltage absorption characteristics and indicated an optimum voltage for reasonable exposure time in the range 25-35 KV.

He also pointed out the advantages of using a continuous film technique in terms of cost and time. Problems of synchronizing motor and film motion might be avoided by a stepping process instead of continuous motion.

H. Zagorites of NRDL had a few words to say about the use of the continuous scan system he has been working with. He pointed out that, being basically a volume sensitive (voids only) system, it would have only limited applicability to the motor case.

D. Polensky of NOL reported on some considerations of fast neutron radiography which showed that fast neutron radiography is not feasible.

He suggested the use of a lead boro-silicate glass end in each roving or in a suitable number of rovings. These are easily detected in x-rays and would show irregularities in winding.

He, also, suggested the use of continuous film in radiography.

Comments and Recommendations

Our requirement is for a quick scan technique that can cover the whole motor including insulator. Defect indications can be identified by supplemental tests. The system should be able to see debonds and delaminations throughout the insulator and case. Propellant-liner or propellant - insulation debonds are not considered part of the motor case inspection, but any system that can detect these as well as motor case defects will gain points.

It is necessary to set up defect test standards. This will be done by SPO with the help of AGC and HPC and anybody else who can and will assist.

SPO will pick one system for scan (with possibly one for backup). Decision will be made after the NDT Committee Meeting in April. Three points are mentioned as basis for decision: 1) Ability to detect flaws; 2) State of Development; 3) Practicality.

The agenda and a list of attendees follow.

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0900	Opening Remarks Statement of Problem	R. W. Smiley, Chairman, SP H. Bernstein
0945	Technical Discussions Status of NDT at AGC	J. A. Hendron, AGC
1015	Hydrotest Analysis	R. Steele, AGC
1100	Low Frequency Ultrasonics	D. C. Erdman, Ultrasonic Consultant
1130	Development of Corona, Microwave and Beta Back-scatter Methods	D. O'Connor, Magnaflux Corporation
1200	Method of Obtaining TV Presentation of Delaminations	P. E. Underhill, AGN
1230	Analysis of NDT Data	A. D. Lucian, AGC
1400	Status of Infrared Development	F. Alzofon/P. Steinkritz, LMSC
1430	Status of NDT Development at ABL	Ron Downey, ABL
1515	Use of Local Heating by Ultrasonic to Enhance Impedance Difference for Flaw Detection	S. Hart, NRL
1545	Mechanical Impedance Measurements	J. Cusick/F. Rand, NAD, Concord

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0900	X-ray and Gamma Scintillation	J. I. Bujes, NAD, Concord
0930	Applicability of Continuous Scanning Systems to Glass Chambers	H. Zagoritas, NRDL, S.F.
1015	Use of Radiation for Inspection of Glass Chambers	Criscuolo/Polansky/Perry, NOL
1045	Summation	S. D. Hart for H. Bernstein, SP

NAME	COMPANY OR AGENCY
Cdr. [illegible] W. Smiley	BUWEPS Rep., Sunnyvale
S. Brannman	AGC
H. Bernstein	SPO
P. A. Steinkritz	LMSC
Donald Erdman	SGC
D. Polonsky	NOL
H. A. Zagoriten	USNRDL
J. A. Hendron	AGC
J. I. Bujes	NAD
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J. L. Rockliff	U.S.NAD, Concord
A. D. Lucian	AGC, Sacramento
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R. E. Legate	AGC
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